3

Shoreline Changes in Westernport Bay

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Abstract: Shoreline changes in Westernport Bay are identified by comparing outlines and features shown on Smythe's map (1842) and Cox's chart (1865) with those on modern maps and air photographs. Apart from sectors of loss and gain on developing sand spits, the most extensive changes have been associated with die-back and disappearance of the mangrove fringe on a number of shore sectors. Field studies have indicated several possible explanations for these changes, including deliberate clearance to provide boat landings, build jetties, form drainage outlets, and harvest wood to be burnt for barilla ash, and the effects of drifting sand, frost action, excessive salinity, current scour, and accumulation of dead *Zostera* within gaps formed in the mangrove fringe.

Shoreline changes can be studied on various time scales. There are relatively long-term changes that have taken place during the period of about five thousand years since the world-wide Holocene marine transgression brought the sea up to approximately its present level, as a sequel to the late Pleistocene low sea level phase. There are the changes that have taken place over the past few centuries, including those within the era of European settlement in Victoria, and there are short-term changes measured over periods from a few years down to a few days, related to seasonal variations in climate or to particular weather events, such as storms or floods.

In Westernport Bay the relatively long-term changes are those which followed the marine submergence of a former coastal lowland to establish the broad outlines of the Bay, together with those of French Island and Phillip Island. They include recession of cliffs on sectors exposed to comparatively strong wave action generated by the prevailing westerly winds, as at Settlement Point near Corinella; deposition of sandy beach ridges and spits, as at Sandy Point and Stockyard Point; and development of extensive mangrove-fringed marshlands, notably in the northern parts of the Bay and in sectors sheltered from strong wave action, as on the eastern shores of Phillip Island. Studies of geomorphological evolution of parts of Westernport Bay over this period have been published by Hills (1942) and Jenkin (1962), but much work remains to be done.

The present paper is concerned with changes during the more limited period of European exploration and settlement, which began when George Bass discovered Westernport Bay in 1798. We have endeavoured to trace these changes by comparing the features of Westernport Bay reported by explorers and recorded on early surveys with the configuration shown on more recent maps, and on air photographs taken in 1939 and 1973-4.

After Bass had discovered Westernport Bay it was visited by English and French expeditions in 1801-2, and then explored by a French party led by D'Urville in 1826. There followed the short phase of British settlement at Rhyll, and later Corinella, in 1826-7. These episodes yielded a sequence of charts compiled by Bass (1798), Barrallier (1801), Faure (1802), D'Urville (1826) and Wetherall (1827) which show versions of the outline of the Bay, but these are not sufficiently accurate for determining subsequent changes. Journals and reports written by the various explorers include incidental references to shoreline features, but proved to be of little value as a basis for assessing changes.

The first detailed survey of Westernport Bay was that made by George Smythe in 1842 at a scale of two-inches-to-a-mile. It was based on a triangulation, and shows the shoreline, together with information on hinterland features, notably vegetation. It provides a document against which the nature and extent of subsequent changes can be identified, providing due allowance is made for possible errors in surveying and cartography (Carr 1962). The accuracy of Smythe's map can be judged only by comparing his rendering of

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the spatial relationships of fixed points, such as clearly-defined rocky headlands and hill summits, with their distribution on modern surveys. There were very few such points within the area mapped by Smythe, but his network of triangulation lines suggests a thorough survey, even where the shoreline was mangrove-fringed. In some of the areas mapped as mangrove he apparently included the tall *Arthrocnemum* scrub which locally grows in the salt marsh to the rear of the white mangrove, *Avicennia marina,* on the shores of this Bay (Fig. 3). Other areas, labelled samphire, were presumably low shrubby salt marsh.

In general, Smythe's map is regarded as sufficiently accurate to be used as a basis for a qualitative assessment of the changes that have since occurred, and in some sectors it is possible to make estimates of the extent of these changes. Fig. 1 shows the shoreline of Westernport Bay as mapped by Smythe, emphasizing the sectors which he showed to be mangrove-fringed. It will be noted that mangroves were then almost continuous from Sandy Point in the west round to the present mouth of Bunyip River on the north coast; they occurred at Red Bluff, south of Lang Lang, and on the shores of Pioneer Bay, round to Corinella.

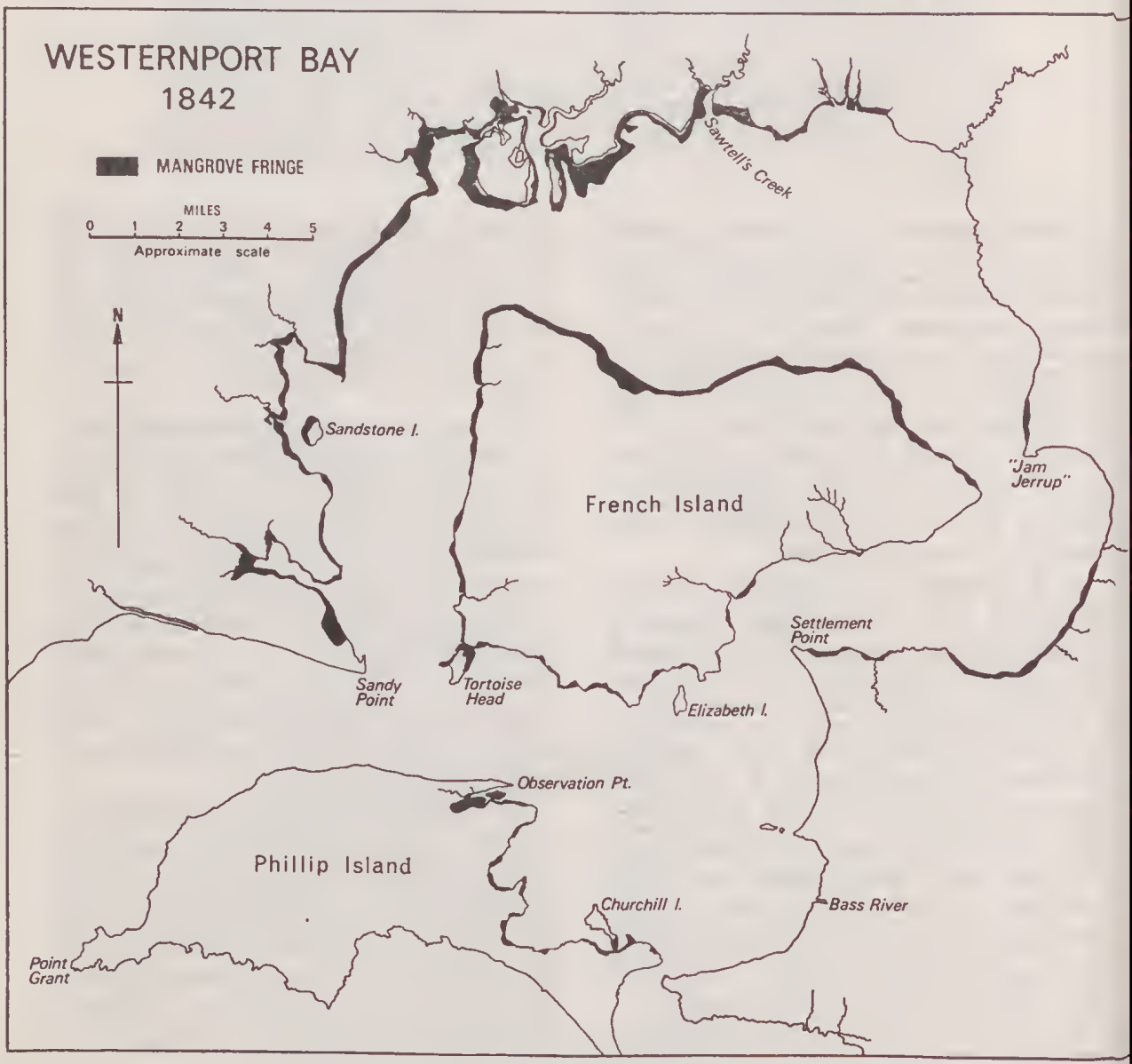

FIG. 1—Westernport Bay in 1842, as surveyed by George Smythe.

Several embayments on the east coast of Phillip Island had mangroves, and they were almost continuous on the western and northern shores, and within embayments on the southern shore of French Island. It is assumed that in 1842 the mangroves were either absent, or too sparse and sporadic to be worth mapping, on the intervening sectors of the Bay shoreline.

In 1865, Cox produced a chart of 'Port Western' (scale approximately one-inch-to-a-nautical mile) which shows the pattern of shoals and tidal channels in Westernport Bay just over a century ago. The working plans on which this chart was based (scale six-inches-to-a-nautical mile) also show details of the shoreline at the time of the survey. These working plans generally confirm the features mapped by Smythe, but show discrepancies in the extent of the mangrove fringe. These could be partly due to cartographic errors and omissions: Smythe probably omitted some sectors of mangrove fringe that were sparse and scattered at the time of his survey, while Cox was primarily concerned with providing a chart for navigators, which must show the form and depth of shoals and channels, but may be less accurate on the details of bordering shorelines, especially

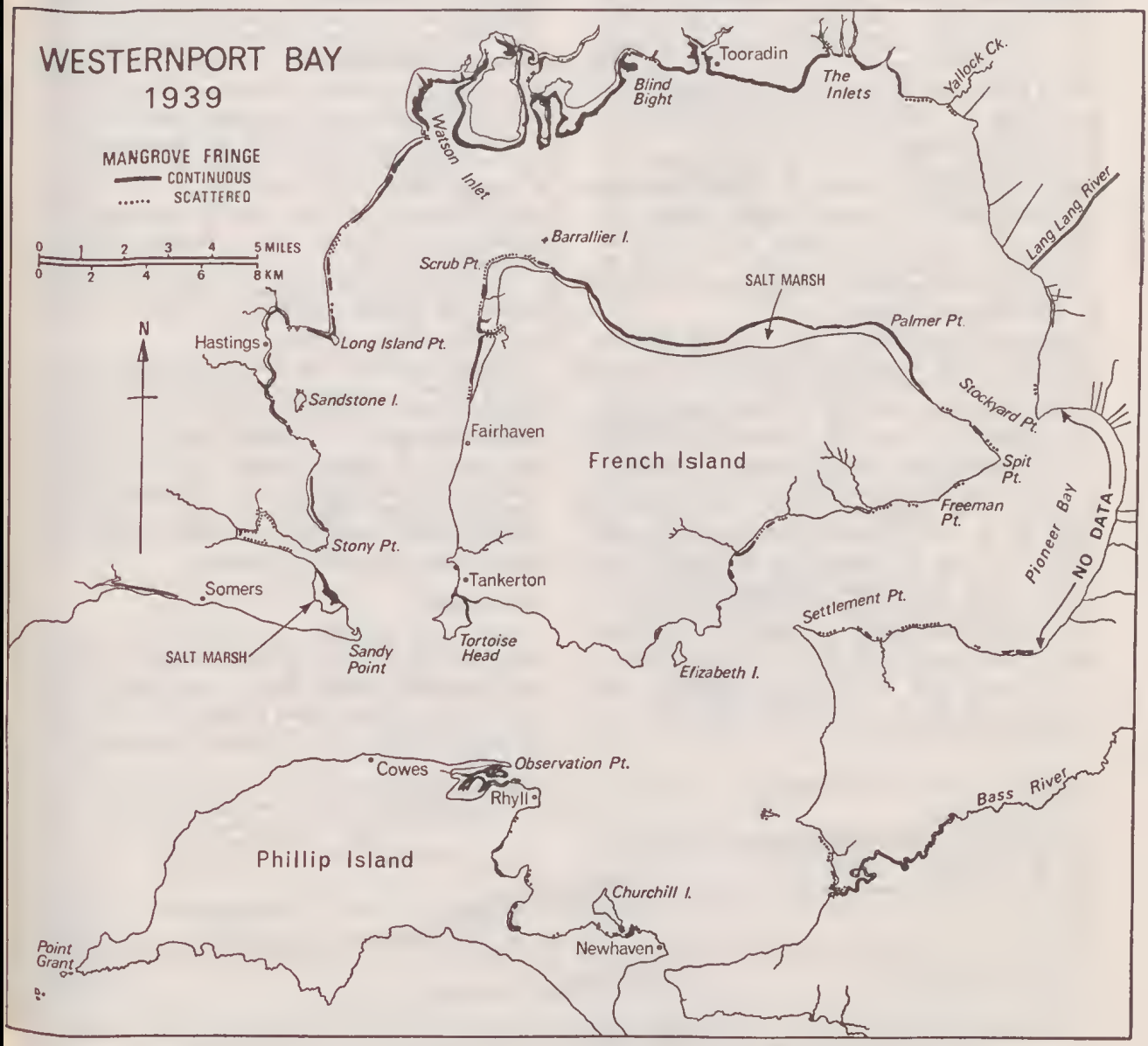

FIG. 2—Westernport Bay in 1939, showing the extent of the mangrove fringe as seen on air photographs.

where these are low-lying and swampy, and lack natural features identifiable as navigation aids. Sectors where the discrepancies between Smythe's map and Cox's chart may represent actual changes in shoreline features between 1842 and 1865 are noted below, but allowing for these, the two surveys provide good evidence of the features of the shoreline of Westernport Bay in the mid-nineteenth century.

Subsequent surveys with which they could be compared include those made in the nineteen-twenties as a basis for the Australian Army Corps 1:63,360 maps of Cranbourne (1924) and Korumburra (1928). Air photographs taken in 1939 were used in compiling the Westernport sheet in this series, and these photographs provide the most reliable source of information on the nature and extent of the mangrove fringe at that time (Fig. 2). When Smythe's map and Cox's chart are compared with more recent maps, revised charts, and modern air photographs it is seen that the broad outlines of Westernport Bay have changed little during the past century, but some sectors of the shoreline have advanced, others have retreated, and there is evidence of changes in the lateral extent and general condition of the mangrove fringe.

Comparison of Figs. 1 and 2 shows that the mangrove fringe mapped in 1842 had become less extensive and more fragmented by 1939. It also appears narrower, but this may be partly due to the inclusion of areas of *Arthrocnemum* scrub within the mangrove fringe as mapped by Smythe. In several sectors, however, the former seaward margin of the mangrove scrub is now indicated only by a few scattered outlying mangroves. Where little or no change has occurred, as on much of the north coast of French Island, the present mangrove-fringed shoreline is backed by salt marsh (dominated by species of *Salicornia* and *Suaeda,* often with areas of *Arthrocnemum* scrub), and then by *Melaleuca ericifolia* scrub (Fig. 3 and Pl. 1, fig. 1). This zonation was probably similar in other areas mapped as mangrove-fringed by Smythe. It is related to tidal submergence, and is thought to indicate a succession of vegetation types that accompanies the gradual building of a bordering marshland terrace by sedimentation and the accumulation of salt marsh peats (Bird 1971).

Sandy shorelines became more extensive in Westernport Bay between 1842 and 1939 as sand drifted into sectors previously mangrove-fringed. There was growth on recurved spits at Sandy Point and Stockyard Point, but the spit at Observation Point on Phillip Island was reduced in length. Recession doubtless continued on cliffed sectors of the shoreline, but Smythe's map is not sufficiently accurate for this to be measured.

By 1974 the shoreline of Westernport Bay had the features shown in Fig. 4. Between 1939 and 1974 there was further reduction of the mangrove fringe, with widening of gaps, extension of areas of die-back, and destruction of mangroves in areas of land reclamation, notably on the shores of Hanns Inlet, where construction of a naval dockyard began in 1912 and has subsequently extended, and adjacent to the modern area of industrial development near Long Island Point. In some sectors, by contrast, there has been a revival and spread of mangroves where in 1939 they were sparse or absent.

Changes continued on sandy shorelines, with further growth on spits, and cliffed sectors continued to retreat, notably on the low-lying coast between the mouth of Yallock Creek and Lang Lang beach. A detailed account of these various changes was prepared for the Westernport Environmental Study (Bird 1974), and in this paper we shall confine attention to selected sectors that show features of particular interest.

Sandy Point

The sandy shoreline that extends east from Somers to Sandy Point has been modified since it was mapped by Smythe, some sectors having been cut back by erosion while others have built forward by deposition. Fig. 5 shows the changes that

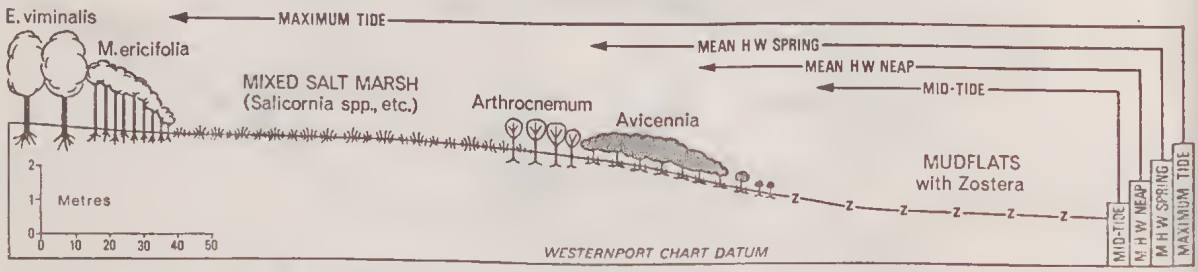

FIG. 3—Zonation of vegetation on marshlands bordering Westernport Bay. In some sectors the tall *Arthrocnemum* scrub occurs farther back, within the salt marsh, and in some it is missing.

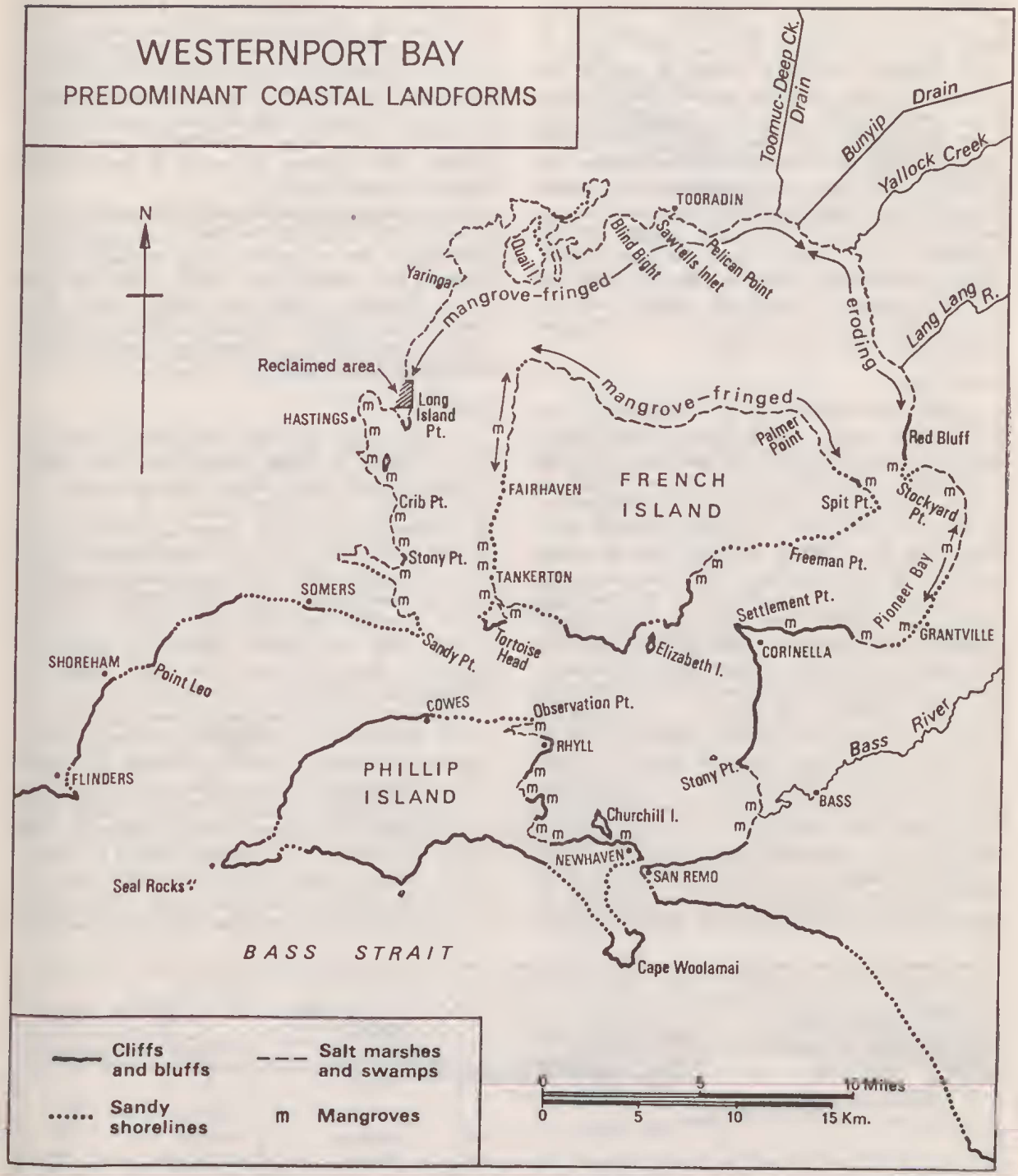

FIG. 4—Shoreline features in Westernport Bay, based on air photographs and field studies, 1974. See also Lands Department Photomap 254 of Western Port (scale approximately 1:100,000), based on 1970 air photographs.

occurred between 1939 and 1972. The broad area of sandy terrain here is marked by a pattern of beach and dune ridges (Jenkin 162, Fig. 16) which indicate a complex history of growth, the outcome of many phases of erosion and accretion on an intermittently prograded shoreline. Longshore drifting of sand has been predominantly eastward, with the result that accumulation has occurred in the form of successive recurves, added to Sandy Point, and since 1939 there has been an eastward advance of the Point, marked by the formation of new scrub-covered and grassy beach ridges. To the north, sand is spreading into the area of mangrove-fringed salt marsh south of Hanns Inlet, and the mangroves have become sparser than they were in 1939.

Stony Point

A gap has developed in the continuous mangrove fringe mapped by Smythe at Stony Point. According to Enright (1973) this was cut prior to 1850 in order that cattle could be loaded on to boats and shipped round into Port Phillip Bay. By 1884 the mangroves had been cleared for a distance of about 200 m on either side of a jetty built out from Stony Point, and it appears that the bluff of Tertiary sandstone to the rear then became an eroding cliff in the sector newly exposed to wave action. Sand derived from this cliff spread across the adjacent muddy foreshore, much of it drifting southwards. By 1939 there had been extensive die-back of the mangrove fringe south of Stony Point, probably due to adverse effects of drifting and deposited sand. The salt marsh which lay behind a sparse mangrove fringe was eroding, and at the same time a sandy beach had developed, and was growing southwards as a recurved spit into Hanns Inlet.

These features can still be traced, but since 1939 there has been substantial regeneration of the mangroves. This is correlated with the building of a wall to halt cliff erosion at Stony Point in 1952, and the ensuing diminution of sandy drift. By 1974 the foreshore was again muddy, and the mangrove fringe was spreading across it in front of the sandy beach (Pl. 1, fig. 2), which in places had been driven up on to the salt marsh to form a perched beach ridge, a landform known as a chenier. The sequence of events is summarized diagrammatically in Fig. 6.

Similar features have developed at several other points on the coast of the Bay where gaps have been cut in the mangrove fringe to permit boat access. These include Crib Point, where the gap in the mangroves shown on Smythe's map, perhaps already made by the early settlers, has since widened, the shore at Hastings, and the boat landing at Denhams Road to the north.

Yaringa

A boat harbor has been developed at Yaringa by excavating a canal across the salt marsh, through the mangrove fringe, and out across the tidal mudflats for a total distance of 1·4 km to the deeper channel which opens southwards from Watson Inlet (Pl. 1, fig. 1). A first attempt to cut such a channel a little to the south was abandoned when it was realized that the mudflats off this sector consisted of deep, soft mud, whereas further north an extensive underlying shell bed offered a firmer substrate for canal extension offshore. Mangroves have recolonized the mouth of the first canal, but the second has been successful in maintaining a navigable approach to the marina established in 1967. Although the mangrove fringe has been interrupted, and bordering levees of dredged material (mainly shells and mud) have been dumped on the adjacent salt marsh, erosion has not ensued; instead the mangroves have advanced in the last few years on either side of the protruding levees. The cutting of a gap through the mangrove fringe to provide

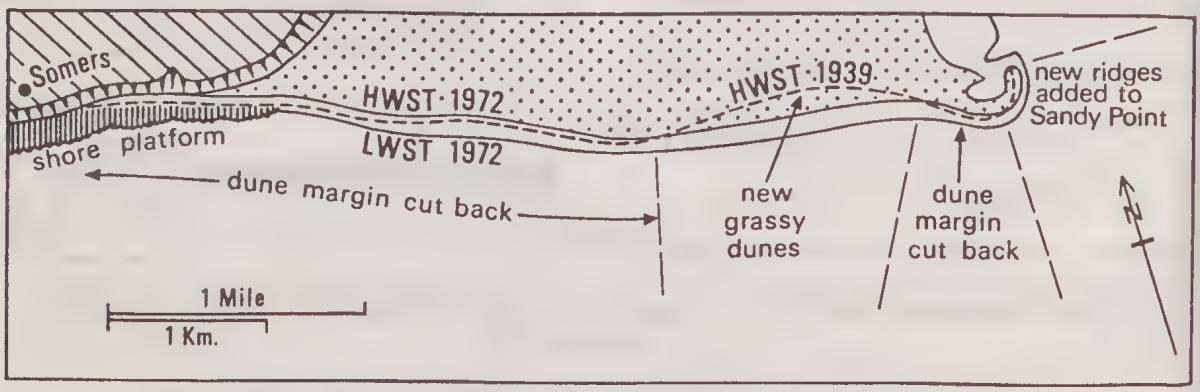

Fig. 5—Shoreline changes between Somers and Sandy Point, 1939-1972.

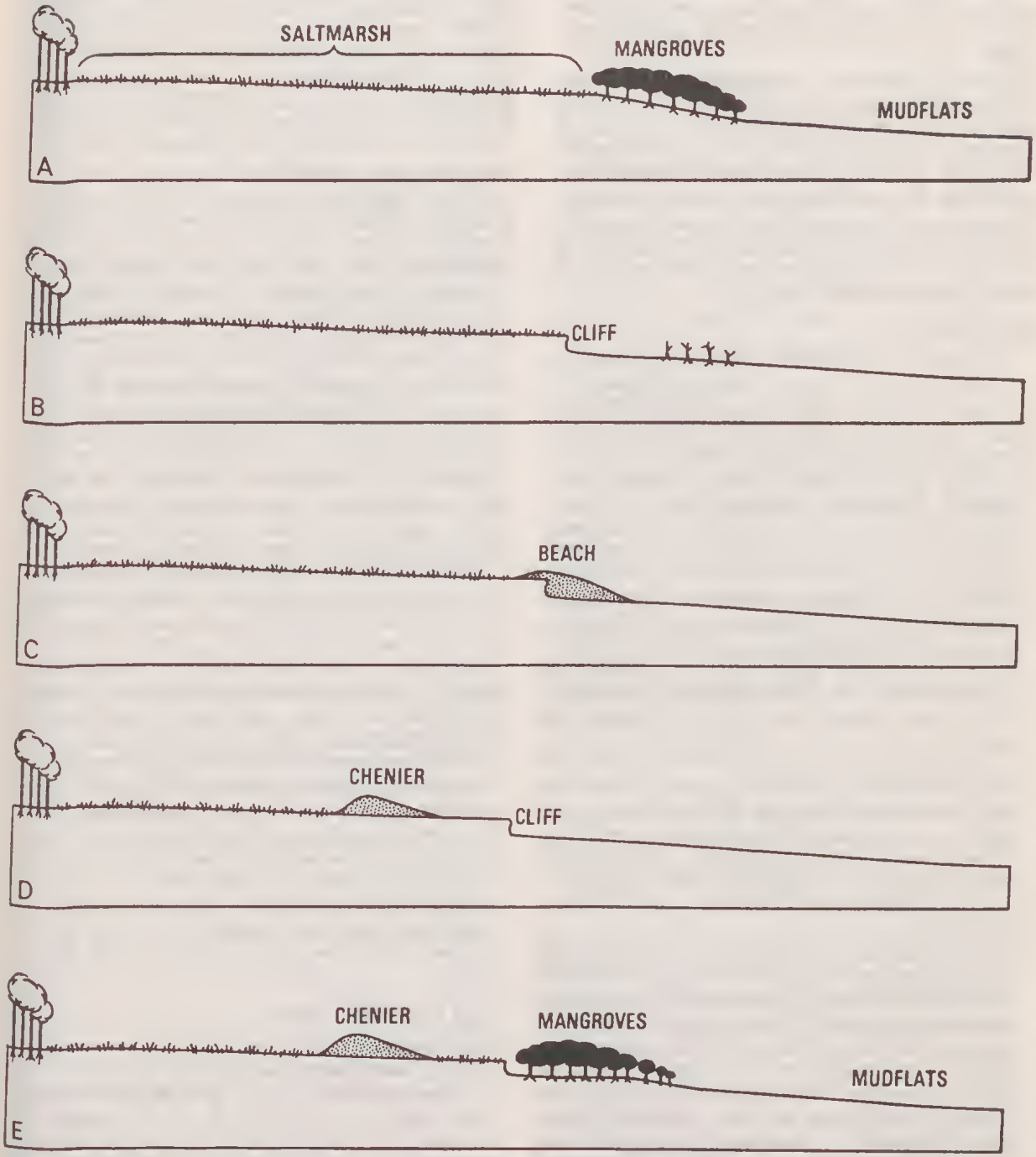

FIG. 6—Sequence of changes on marshland shores in Westernport Bay when the mangrove fringe (A) dies back or disappears. Erosion of the salt marsh occurs (B), and a beach of sand washed onshore or alongshore may then accumulate at the outer edge of the salt marsh (C), and be driven up on to it by storm waves at high tide, forming a chenier (D). In some sectors, this sequence has been followed by recovery of a mangrove fringe in front of the eroded salt marsh (E).

boat access here has not resulted in mobilization of sandy drift, and so the adjacent tidal flats remain muddy, and mangrove growth continues without the die-back and erosion seen at Stony Point.

South of Yaringa, measurements of surface levels over a three-year period showed sustained vertical accretion within the mangrove fringe in contrast with irregular sequences of accretion and erosion on the adjacent mudflats. From this it was concluded that the mangroves are promoting sedimentation and causing the aggradation of a depositional terrace to mean high spring tide level, whereupon the mangroves are succeeded by salt marsh vegetation (Bird 1971).

Blind Bight

In 1842 the mangrove fringe was continuous here, but by 1939 a gap had formed on either side of the outlet from the Main Western Contour Drain opening into Blind Bight. This change was correlated by Enright (1973) with the effects of the scour that developed when the outflow from Dalmore Swamp was diverted from its former seepage towards Sawtells Inlet into this drainage channel, the excavation of which was completed in 1938. During, and for some years after the excavation, the outflow carried sandy sediment (derived from the Cranbourne Sands formation which extends beneath the peat deposits) on to the shores of Blind Bight, and this produced an environment that was unfavourable for mangrove growth and regeneration. Salinity dilution by drainage water was an additional factor adverse to mangroves. In recent years there has been a return of muddy sediment to part of the area that had become sandy in 1939, and as a consequence, there has been substantial regeneration of mangroves and salt marsh in sectors that in 1939 were devoid of vegetation (Pl. 1, fig. 3).

The Inlets

When Smythe made his survey The Inlets were a series of meandering tidal creeks opening on to a mangrove-fringed shore, backed by the extensive freshwater swamps of Koo-wee-rup. A number of streams, including the Bunyip River, flowed into these swamps to disperse amid rushes, reeds, and 'tea-tree', mainly swamp paper-bark (*Melaleuca ericifolia*), and there was only a gradual seepage filtering through to the mangrove-fringed shoreline (Hills 1942). After very wet weather there was extensive flooding, and water overflowed noisily into the Bay through the tea-tree at The Inlets (Gunson 1968).

Drainage of Koo-wee-rup swamp began with small-scale, piecemeal schemes in the eighteen-seventies, and progressed in stages, with phases of improvement and enlargement of drainage canals right through to the present day (Key 1967). Drains were cut to open into each of The Inlets, but the major schemes brought the Cardinia Drain and the Toomuc-Deep Creek outfall (the latter completed in 1937) into Cardinia Creek and Moodys Inlet respectively and the Main Catch Drains into the Bunyip Drain, the outlet that had been made for the Bunyip River.

As in Blind Bight, there was disruption of the mangrove fringe and erosion of salt marsh on the shoreline adjacent to these outlets by the time air photographs were taken in 1939. Again, this is attributed to the effects of drainage schemes. These facilitated runoff from the reclaimed Koo-wee-rup Swamp and concentrated it at the mouths of the creeks, thereby intensifying scour, reducing salinity, and injecting large quantities of sand and gravel (derived from deposits beneath the swamp peat) into an environment that was previously muddy. At low tide the banks of the channel off the mouth of Bunyip River show sections of up to 50 cm of alternating layers of sandy gravel and mud, representing accretion during successive phases of strong outflow and sand yield from the Main Catch Drains alternating with quieter periods when muddy sedimentation returned. Key (1967) mentions flooding in the Koo-wee-rup area in 1893, 1900, 1901, 1911, 1916, 1923, 1924, 1934, 1935, 1937, and 1952, and it is likely that each of these floods yielded an outwash of coarse sediment. Locally there are beaches derived from outwashed sand and gravel, and in some sectors these have been driven up on to the salt marsh, probably in episodes when strong southerly wave action accompanied high tides, to form cheniers. In recent years, flooding has been less frequent and the drainage channels have become relatively stable, with the result that muddy sediments are now again extensive, and there has been some regeneration of mangroves on and in front of the eroded salt marsh (Pl. 2, fig. 4).

The Lang Lang Shore

Between the mouth of Yallock Creek and the pier at Lang Lang Beach there is a long sector of receding cliffs up to 2 m high in black cracking clays (Pl. 2, fig. 5 & 6). On Smythe's map this shoreline is shown as irregular and much indented, without any mangrove or salt marsh fringe, and the black clay terrain of its hinterland carried an extensive paper-bark swamp, through which floodwaters drained out into the Bay. It is probable that this sector of shoreline was cliffed and receding in 1842; indeed, it may well have been

retreating ever since the Holocene marine transgression arrived in Westernport Bay and brought wave action to the seaward margins of Koo-wee-rup swamp (Hills 1942). Smythe's map is labelled 'numerous rills of fresh water continually running forming the outlet from the swamps', and it is possible that floodwaters spilling out in this way produced the crenulate shoreline, with waterfalls scouring out each small cove.

Under natural conditions, the Lang Lang River dispersed into this swamp, but between 1880 and 1920 the area was gradually drained and reclaimed for agriculture, and an outlet was cut to take the river through to the Bay shore. This was widened in 1913 and further improved and embanked in 1937, and its effect has been to concentrate the outflow and reduce the occurrence of floodwaters spilling out along the length of the shoreline. Nevertheless, erosion has proceeded, and Gell (1974) has demonstrated recession of the shoreline, with a simplification of its outline in plan, over the period since Smythe's survey. The clay cliffs are reached by waves for only a small portion of each tidal cycle, and much of the erosion takes place intermittently, when storm waves accompany high tides. Comparison of air photographs taken in 1939 and 1973 shows a general shoreline recession of 10 to 20 m, and locally up to 50 m (Gell 1974).

Red Bluff and Stockyard Point

Red Bluff consists of cliffs up to 15 m high in Tertiary sands, sandstones and clays. In 1842 a sector extending south from the Bluff had a mangrove fringe, but by 1939 this had become very sparse, and now there are only a few scattered and elderly mangroves persisting in sandy mud. Depletion of the mangroves here may have been a result of the use of this sector of shore as a convenient loading and unloading area for cattle and produce shipped in and out of Westernport Bay in the mid-nineteenth century. Some of the mangroves may have been cut and burned to produce barilla ash, exported from here to England for use in soap manufacture in the eighteen-forties (Gunson 1968). With a natural source of sandy drift in the cliff at Red Bluff this must have been a marginal environment for mangrove growth and regeneration, and any mangroves cut would not easily have been naturally replaced.

Sand eroded from Red Bluff has drifted both northwards to form the narrowing beach extending to north of Lang Lang pier and southwards to Stockyard Point (Nicholson 1974). The longshore drift results mainly from wave action at high tide. Strength and frequency of this wave action is related to the wind regime and to lengths of fetch, and here the longer north-westerly fetch gives a dominance of waves from this direction over those arriving from the short south-easterly fetch, so that southward drifting has been more important than northward drifting in dispersing sand derived from the cliff at Red Bluff. Sand that has drifted southwards has been deposited in a series of recurved ridges at Stockyard Point (Jenkin 1962, Fig. 17). Each ridge is capped by low dunes bearing scrub or grassy vegetation, and there are intervening areas of salt marsh. The western shoreline has been cut back, transecting some of the earlier recurves, but southward growth by sand accretion has continued since Smythe made his survey, and an additional sand ridge has been built up between 1939 and 1973 (Pl. 3, fig. 7).

Pioneer Bay

The extensive sectors of mangrove shore mapped by Smythe have been much reduced in Pioneer Bay, especially in the vicinity of Grantville, Queensferry, and Corinella, where gaps were cut in the mangrove fringe to permit boat access and the construction of piers. On the southern shore between Queensferry and Corinella, Cox mapped a more extensive mangrove fringe than had been recorded by Smythe 23 years previously, which may indicate some regeneration after an initial phase of mangrove clearance by early settlers around 1840, when Westaway's run was first licensed.

Bass River Mouth

The estuarine meanders of Bass River wind through an extensive area of salt marsh to open on a broad, shallow tidal embayment (Jenkin 1962, Fig. 8). Smythe's map shows no mangroves on this shore, but he indicates their presence here in his field book. In 1865 Cox charted them in two areas, one to the north and the other to the south of the river estuary, and there are mangroves in these areas now (Pl. 3, fig. 8). At present they fringe the lower reaches of Bass River and are extensive on the muddy shore to the north, where they have advanced further on to the soft mud since 1939. To the south the shore becomes sandy, the sand having drifted into Westernport Bay through the eastern entrance near San Remo, thence across the floor to be washed up on the broad gently-sloping inter-tidal zone. In the presence of drifting sand, only a few old mangroves survive. So far, northward drift of sand has been impeded by the outflow from Bass River, so that a marked sedimentological contrast is maintained between the northern and southern

sectors. The shore here has recently been colonized by *Spartina anglica,* an introduced halophytic grass that has spread from initial plantings in the estuary at Bass Landing (K. G. Boston, pers. comm.).

Observation Point

North of Rhyll the coast consists of steep bluffs in weathered basalt, which pass along the southern shoreline of an estuarine area known as The Nits (Jenkin 1962, Fig. 15). The northern margin of this estuary is an elongated sandspit with several recurves, built up by the drifting of sand eastward along the north coast of Phillip Island. It now terminates in Observation Point, but at an earlier stage it had grown farther eastward, as is clear from the illustration of the 'crique des mangliers' that accompanied D'Urville's (1826) report of his visit to Westernport Bay (Bowden 1970, f.p. 21). An outlying sandy islet shown on Smythe's map and Cox's chart has been eroded away during the past century. However, comparison between air photographs taken in 1938 and 1973 show that Observation Point has recently resumed its eastward growth.

Sheltered by Observation Point, the estuarine area is largely mangrove-fringed, with salt marshes to the rear. Smythe mapped a mangrove fringe on the southern shore, a substantial area of mangroves to the west (now mainly salt marsh, but this may have been an error by Smythe rather than evidence of a vegetation change), and a central mangrove island, but omitted to indicate mangroves on the northern shore. Cox's chart includes these, but shows a much reduced area of mangroves on the southern shore. By 1938 there were certainly gaps in the mangroves on the southern shore, notably near the quarry, and on either side of the cattle landing to the west. There is now an eroded embayment in salt marsh in front of the abandoned quarry, where thin muds mantle a platform cut in Mesozoic rock, flanked by surviving mangrove stands. This gap was probably cut to give boat access to the shore, and has widened out with the spread of sandy sediment derived partly from overspilled quarry waste. At the cattle landing there is an extensive area where mangroves have died back, except for a few surviving shrubs along the seaward margin (Pl. 3, fig. 9). This is not a sandy area, and the die-back must be due to some unfavourable ecological condition (see discussion below).

Fairhaven

The mangrove fringe mapped by Smythe on the west coast of French Island has been much reduced, and there has been erosion of salt marshes and accumulation of drifting sand. In the sector north from the ruined jetty at Fairhaven, occasional surviving mangroves mark the former seaward limit of the mangrove fringe. The shore consists of very soft mud, with a superficial admixture of sand, and a sandy beach extends northward as a spit, fingering into the salt marsh behind an area which is still mangrove-fringed (Pl. 4, fig. 10). The features here are due to the widening of gaps originally cut through the mangroves to provide boat access: mangroves were originally able to establish on a muddy substrate despite exposure at high tide to waves generated by the prevailing westerly winds, but in the presence of sandy drift there is no regeneration.

Scrub Point

The north-western corner of French Island was shown on Smythe's map to have a continuous fringe of mangroves backed by salt marsh. On Cox's chart, surveyed in 1865, a wide gap is shown in this mangrove fringe, and a sector of sandy beach borders the western shore. By 1939 there had been revival of mangroves in front of this sandy beach (cf. Fig. 6), and there are now patches of live mangroves alternating with areas of dead mangroves and sectors where they have disappeared altogether (Pl. 4, fig. 11). Some of the gaps are correlated with the cutting of drainage ditches to let water run off the salt marsh, and show on a small scale features similar to those at The Inlets and Blind Bight, except that in this sector the sand drift appears to have been washed in from the Bay floor. There are some areas of dead mangroves, with surviving shrubs and trees at the outer margin, similar in pattern to the features described from the southern shore of The Nits. Other gaps may have been cut originally for boat access, or to harvest mangrove wood to be burned to make barilla.

Spit Point

The easternmost point of French Island is shown as Sandy Point on recent maps, but to avoid confusion with Sandy Point on the western shore of the Bay we will revive the name Spit Point, used on Cox's chart in 1865. Spit Point is a cuspate foreland, with sandy beach ridges and low dunes similar to those on Stockyard Point, enclosing an area of salt marsh. Since 1842 the point has grown out to the south-east, a marked extension in this direction being seen when air photographs taken in 1973 are compared with those of 1939. On the northern side, where Smythe showed a broad mangrove fringe, there are now only a few mangroves growing in soft sandy mud in front of the sandy beach. It is

thought that mangroves were being cut and burned to produce barilla ash on this part of French Island in 1843-4 (F. J. Bird, pers. comm.), and it is possible that this exploitation depleted the mangrove fringe.

Smythe's map shows no mangroves on the shore south-west from Spit Point to Freeman Point, whereas Cox's chart shows several sectors of mangroves here in 1865. Smythe's omission of mangroves could have been an error, or it could have indicated that in 1842 they were sparse or absent here, and that regrowth of mangroves had occurred by the time Cox charted this sector 23 years later. By 1939 they were again sparse, and under present conditions their regeneration is prevented by the extensive sandy drift arriving from the south.

Tortoise Head

Tortoise Head is a former island of Tertiary basalt, which by the time Smythe made his survey had been almost tied to the south-west of French Island by an isthmus of mangroves, through which ran an open tidal channel. This has been subsequently sealed off by sand deposition and swamp encroachment at its western end, and comparison of 1939 and 1973 air photographs shows that mangroves fringing this channel have further advanced, reducing its width (Pl. 4, fig. 12). The extent of mangroves on the eastern and western shores of Tortoise Head has otherwise diminished since Smythe and Cox made their surveys. Much of the area north of Tortoise Head mapped as mangroves by Smythe is now salt marsh, but again it is impossible to decide whether this represents an actual change in vegetation, or whether he included salt marsh then existing within his mangrove area. This is one of the few areas of continuing mangrove advance on the shores of Westernport Bay, where it is possible to study the features that must at one stage have been widespread, when mangrove spread initiated the building up of the salt marsh terrace bordering Westernport Bay.

DISCUSSION

Apart from the sectors of gain and loss on developing sandspits and the recession of bordering cliffs the most obvious changes on the shorelines of Westernport Bay since 1842 have been those resulting from die-back, destruction, and deliberate clearance of the mangrove fringe. The few gaps that Smythe mapped have become wider, and other gaps have formed, notably where the mangroves have been cut to create boat landings, build jetties or harbors, or allow runoff to escape from drainage canals and ditches. Parts of the mangrove fringe have been embanked and infilled to reclaim land bordering the Bay shore.

In addition to these direct effects of man's activities, it is evident that sectors of the mangrove fringe have died back, and in some sectors disappeared. While there is no single explanation that will cover all cases, it is clear that the arrival of drifting sand in areas where mangroves formerly grew in soft mud has impeded their growth and regeneration. In some sectors this is a natural process, notably where a sand spit is growing into a mangrove swamp (e.g. north of Sandy Point), but in others it results from the mobilization of sand eroded from cliffs, washed up from the Bay floor, or carried in by drainage channels, as a consequence of man's impact on the Bay, its shores, and its hinterland. Further work is needed to determine the physiological changes that occur when drifting sand arrives in a mangrove swamp.

Damage to mangroves by frost action is a possibility in Westernport Bay, where *Avicennia marina* is growing close to its climatic limit: Australia's southernmost mangroves occur in Corner Inlet at latitude 38° 55′ S. Frosts occur several times a year at Tooradin on the northern shore of the Bay, and in 1965 the mangroves were damaged here during a severe frost (Ashton 1971).

Mangroves can also be killed by the effects of reduced salinity when fresh drainage waters are diverted into them, or by very high salinity, which is unlikely to occur on open shores where there is free circulation of sea water, but may develop in areas of impeded drainage, as in the lee of a growing spit. In such sites, however, mangroves are more likely to succumb to waterlogging as they did within the area embanked for reclamation at Hastings in 1967. Nevertheless, Ashton (1971) reported an example of small mangroves apparently killed by high salinity on the marsh at Warneet during the dry summer of 1968.

Toxic chemicals present in industrial effluents are likely to damage or destroy mangroves, but no definite example of this has yet been observed in Westernport Bay. Accidental drifting of a herbicide spray is thought to have defoliated mangroves near Queensferry.

In the course of our field work we noted that large quantities of dead *Zostera* are washed up on parts of the shoreline of Westernport Bay, especially on beaches and in sectors where there are gaps in the mangroves. Examples of mangroves completely blanketed by this *Zostera* hay were observed, the outcome being at least temporary defoliation. In some places the deposition of a wet, decaying mat of *Zostera* over pneumato-

phores had apparently killed mangroves. *Zostera* does not accumulate where the mangrove fringe is intact, presumably because it is floated by every high tide, and can be readily dispersed, but where gaps have been cut in the mangrove fringe, dead *Zostera* is washed in, and can build up a substantial blanket of decaying weed. The possibility that this accumulation plays a part in widening artificial gaps deserves further investigation: it could account for the features of mangrove dieback noted on the southern shores of The Nits, and near Scrub Point on French Island.

The changes that have been identified in the mangrove fringe of Westernport Bay are largely due, directly or indirectly, to man's activities. Where mangroves have died back or disappeared there has been increased instability, marked by the onset of erosion of salt marshes and drifting of sand, but where the mangrove fringe persists there are relatively stable physiographic and ecological conditions. In terms of conservation, it would be wise to avoid any further disruption of the mangrove fringe in Westernport Bay, and to attempt to restore mangroves in areas where they formerly grew. In some sectors this would mean little more than protecting the mangrove seedlings that develop each year until they reach a stage of sufficient maturity to persist as a regenerating scrub community. The high mortality observed in mangrove seedlings on tidal flats under present conditions requires investigation in order to devise appropriate management techniques, but where drifting sand is a limiting factor the creation of a transverse ridge-and-furrow topography could provide sufficient stability to enable naturally occurring or planted seedlings to mature. Where the mangrove fringe is still in retreat, as to the north of Fairhaven, insertion of a groyne may be necessary to halt the inflow of drifting sand.

There is a possibility of creating new mangrove and salt marsh areas to balance some of the losses incurred during the past few decades. Thus the elongated shoal off the west coast of French Island could be artificially raised by dumping dredged sediment to a level where it could sustain vegetation, and this in turn would shelter the adjacent coast, and assist with the restoration of a mangrove fringe there. The advent of the Westernport Environmental Study is implicitly a prelude to deliberate management of the Westernport Bay system, which should include the conservation, restoration, and creation of sufficient areas of mangrove and salt marsh to ensure relatively stable physiographic and ecological conditions, provide an acceptable coastal scenery, maintain productivity (notably of fisheries), conserve wildlife, and perpetuate the scientific interest of Westernport Bay.

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DESCRIPTION OF PLATES

PLATE 1

FIG. 1—The north-western part of Westernport Bay, showing the mangrove and salt marsh fringe and the canal cut at Yaringa boat harbor.
FIG. 2—Sandy beach south of Stony Point, now fronted by mangroves. Note strandlines of *Zostera* weed.
FIG. 3—The shore at Blind Bight, showing the gap in the mangroves off the mouth of the Main Western Contour Drain.

PLATE 2

FIG. 4—The shore at The Inlets: Moodys Inlet (foreground), Cardinia Creek, and Lyalls Inlet. Mangroves are reviving here after depletion in the nineteen-thirties.
FIG. 5—The eroding shoreline near Lang Lang, viewed from the south-east.
FIG. 6—Eroding cliffs in black clay on the shoreline near Lang Lang.

PLATE 3

FIG. 7—Stockyard Point, viewed from the south, with Red Bluff in the background and a few surviving mangroves on the sandy shore.
FIG. 8—Mangroves and a clone of *Spartina anglica* on the shore north of the mouth of Bass River.
FIG. 9—Area of dead mangroves on the southern shore of The Nits near Rhyll.

PLATE 4

FIG. 10—The shore at Fairhaven, on the west coast of French Island, where mangroves have been reduced and a sand spit has grown into the salt marsh.
FIG. 11—Scrub Point, north-west French Island, where the mangroves have become sparse and a sandy beach has developed on the salt marsh to the rear.
FIG. 12—The mangrove-fringed tidal creek near Tortoise Head, French Island.